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TITLE: MIXED MODE OPERATION IN CTX

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Mixed Mode Operation in CTX

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Spheromaks with temperatures greater than 100 eV have been routinely made in CTX with "slow" formation techniques.[1,2] A second high inductance-low current source was added to drive additional current in the spheromak in an attempt to sustain it resulting in the mixed mode of formation. Figure 1 shows the current for both the mixed mode and the slow mode of operation. Fig. 2 shows the power input at the electrodes for the mixed mode. The peak of the additional power is typically 10 Mw to 20 Mw; however, the power input to the electrodes is only an upper bound to the power injected into the spheromak.

Improvement of Spheromak Parameters

Thomson scattering measurements were taken interchangeably in both the slow and mixed modes over a two-week period under otherwise the same vacuum and operating conditions. During the hottest portion of the discharge (400 - 600 μs) there are many discharges possibly above 150 eV which exceed the ability of the T.S. instrument to measure accurately the temperature. Figure 3 shows the result of comparing the measured core (between 21-31 cm in radius) temperature average in this set of slow and mixed mode shots. Care must be used in rejecting or accepting fits for some of the hottest discharges to avoid bias in the comparison. However, there does appear to be a consistent 15-30 eV increase in the average core temperature during the time power (of ~ 10 MW) is being applied at the electrode. As shown in Fig. 2, it appears that after ~ 650 μs power is no longer injected into the spheromak. The temperature in the mixed mode then decays at the same rate (but delayed by 200 μs) as the slow mode spheromaks. The mixed mode thus results in lifetimes that are typically 200 μs longer than in the slow mode. Additional current (overdriven mixed mode) resulted in colder spheromaks than either the slow or mixed mode cases. The reason for this is not clear although the impurity levels do become much higher for the overdiven case[2], magnetic field lines for the outer flux surfaces are still connected to the source, and the n = 1 mode that is observed may adversely affect the plasma temperature.

Stabilization of the n = 2

During mixed mode operation, the n = 2 oscillations no longer appear after formation. Figure 4.a. shows the poloidal and transverse fields on axis for a slow mode discharge, illustrating the rotating helical kink observed on the geometric axis. Figure 4.b. shows the same fields during a mixed mode discharge, the oscillations of the transverse components have been eliminated by the additional current. Rogowski loops measuring induced surface currents in the flux conserver confirm the elimination of the rotating mode. Stabilization is expected because of the current profile modification and a flattening of the j/B profiles.[3] For the slow mode generated spheromaks, the plasma is colder on the outer flux surfaces and the current decays faster than on the innerflux surfaces leading to the n = 2 oscillations. Mixed mode operation sustains these outside currents and flattens the j/B profile. Overdriven, mixed mode operation raises these currents too high and the n = 1 oscillation appears (Fig. 5).

Summary

Mixed method of operation with input powers of 10 MW to 20-MW results in hotter ($\Delta T_e \sim 30$ eV) longer lived spheromaks (~ 200 μs longer) than slow mode operation. However, a further increase in driving current is detrimental to the temperature of the spheromak (possibly due to the injection of impurities). In the mixed method, n = 2 oscillations no longer appear during the decay, apparently due to the sustainment of currents in the outer flux surfaces. This sustainment leads to more uniform j/B profiles, which may stabilize the n = 2.

References

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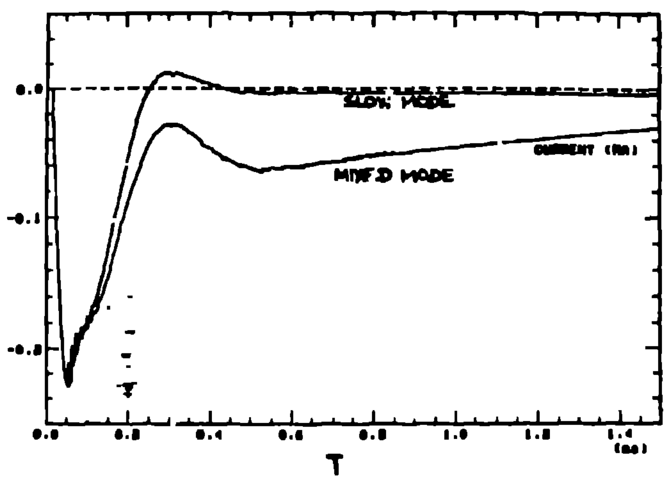

Fig. 1. Slow and mixed mode currents.

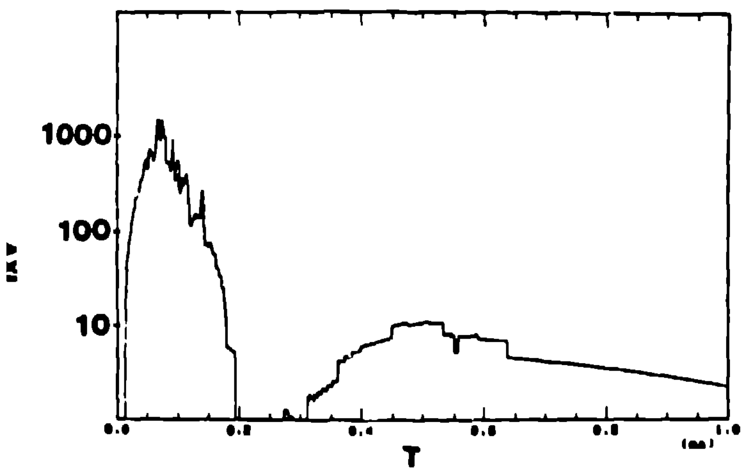

Fig. 2. Power input to the electrodes for mixed mode operation.

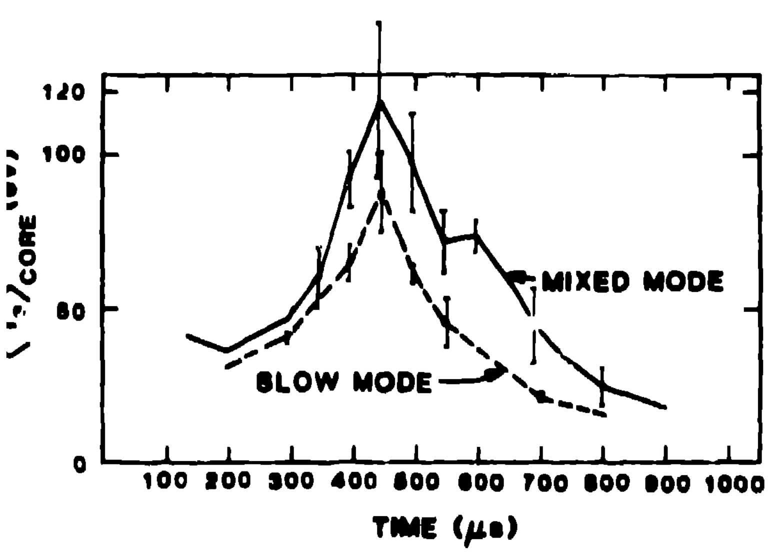

Fig. 3. Core temperatures for mixed mode and slow mode operation.

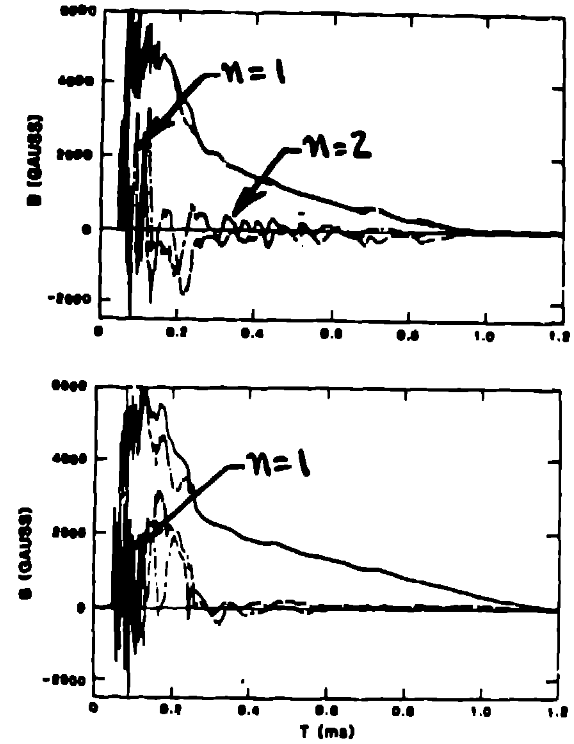

Fig. 4 a) B fields on the geometric axis for slow mode operation and for b) mixed mode operation.

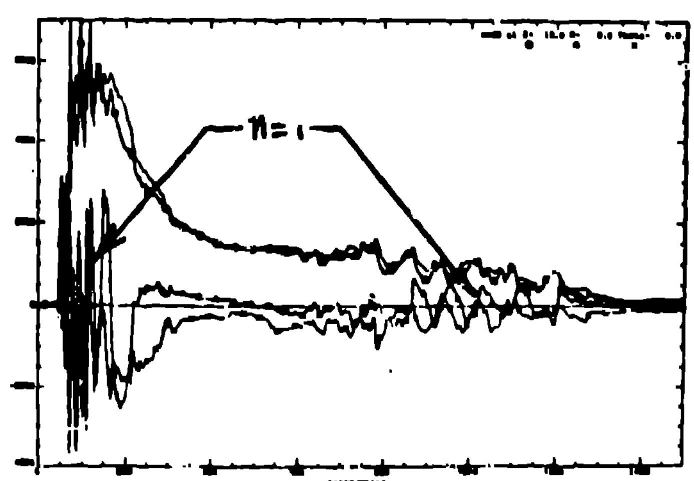

Fig. 5. B fields on the geometric axis for overdrive, mixed mode operation.